Demystifying the behavior of granular media by a micromechanics-based plasticity model

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Granular materials are ubiquitous and important to our everyday life. They are seen in form of both natural and engineering materials, such as sand, sugar, food grains and powders in agricultural, pharmaceutical, energy and chemical industries. Indeed, granular materials are the second-most manipulated material in the industry (next to water). As a typical example of granular media, sand is important to a wide range of key infrastructures pertaining to the quality and safety of our daily life and the economy of many countries around the world. Many new infrastructures such as wind turbines, high-speed railways, tunnels, pipelines and earth dams which are lifelines to the economy of many countries will be unavoidably built on/in sand. The mechanical behavior of sand underpins the critical performance and serviceability of these structures and is the key factor to be considered in their design, construction, operation and maintenance. Due to the geological deposition process, most sands exhibit highly anisotropic fabric structures which are closely associated with preferentially orientated particles, void spaces and interparticle contacts. Fabric anisotropy has profound effect on the mechanical behavior of sand and thus influences such phenomena as embankment failure and soil liquefaction (the contact forces between sand particles are so low that the sand behaves like liquid) which can cause catastrophic hazards to both human lives and properties. If the soil is assumed isotropic, the associated geotechnical design will be either too dangerous or too conservative. For instance, back-analysis indicated that liquefaction failure of the Lower San Fernando Dam in 1971 has been due to neglecting of the fabric effect on sand liquefaction resistance in design.

This project aims to develop a micromechanics-based plasticity model for sand accounting for effect of sand anisotropy and its evolution.

Robust, efficient and accurate numerical technique will be developed to implement the proposed model in the finite element software package Abaqus which is widely used in geotechnical design and research. The model will then be used to do improved analysis of some challenging geotechnical problems through collaboration with industry. Engineering protocol for considering soil anisotropy in geotechnical design will then be developed based on the numerical analysis and its application in real geotechnical problems.